OCEAN TIDE CHARTS IN THE MEDITERRANEAN SEA

R. Vieira and C. de Toro

Instituto de Astronomía y Geodesia (C.S.I.C.-U.C.M.)
Facultad de Ciencias Matemáticas
Ciudad Universitaria, 28040 MADRID. SPAIN.

ABSTRACT

We present in this paper a synthesis of the first stages of modeling the main constituents of the ocean tides in the Mediterranean sea. We have initiated our work with the construction of the M2 harmonic chart for the whole sea. At the present stage we have obtained the results corresponding to its western basin, from the Gibraltar Strait till the islands of Corsica and Sardinia.

1. INTRODUCTION

The need of a good modeling of the ocean tides in areas close to the Iberian Peninsula came out as a consequence of the Earth Tide investigations carried out by the I.A.G. since 1973. Since 1981, the ocean effects, which greatly disturbs the observations of the gravimetric, clinometric and extensometric tides, especially in stations close to the coast, have been determined on the bases of the NSWC global models (Schwiderski, 1980) of eleven most important harmonics of the tidal potential. However, these charts need to be completed for two reasons: first, because Schwiderski, in his models, does not consider some seas such as the Mediterranean and, second, because it is generally problematic that the global charts can reflect some of the geographic and hydrodinamic characteristics with important influence on the tides in the coastal areas. For these reasons, like other groups of investigators used to do in their close areas, we started an investigation for the creation of the so called Iberia charts. The investigations were later extended to the atlantic area of the Canary Islands (Vieira et al. 1983, 1986, 1991; Toro, 1989).

The charts built up to now are based on tidal observations in coastal and deep stations, in the nearby areas of the studied zone, as well as in distant areas. The handling of a great number of records has made necessary a data base whose design and logical organization has been built up by taking on account the different applications of those data. Now a days, the data bank is integrated by the information of 291 tidal stations among which 105 coastal stations located in the Mediterranean sea, 20 are in the Gibraltar Strait and the remaining are located in the atlantic region next to the Iberian Peninsular and the Canary Islands; 53 of the later ones correspond to pelagic observations. The number of the records in the data bank in its actual state is of 30975.

In the Iberia and Canary charts we have imposed as a boundary condition the phase and amplitude isolines to link without discontinuity with the charts of the global model NSWC (Schwiderski, 1983). This is a logical consequence of the certified accuracy of such charts and the recommendations of different International Commission to use them as a standard tool for geodesic and geophysical applications. Obviously, in the case of the Mediterranean sea, we are only interested in linking through Gibraltar Strait with the near atlantic area.

With this work we are offering the results corresponding to a first modeling of the main semidiurnal component with lunar origin M2 for the western area of the Mediterranean sea between Gibraltar and the 8^{o} E meridian. As we have already commented, in this first trial model we have only used tidal data from the coast as we do not have information available from pelagic observations from the Mediterranean sea. In spite of it, when continuing this work, once its influence evaluation will be carried out, we will take into account some other factors such as bathymetry, shape of the basin, the amplifying effects and non-linear interactions between the harmonics in shallow waters, etc.

2. SETTING LIMITS AND DIVISION AREAS

The area of our interest includes not only the Mediterranean sea, which is not modeled by Shwidersky, but also the atlantic regions near the Iberian Peninsula and the Canary islands. Confining our work to the Mediterranean sea, we have carried out a division by zones taking mainly into account what we can call natural barriers (figure 1). This zonal division is also indicating the progression in our modeling work, initiated by the indicated figure as the first one, which corresponds to western Mediterranean. Obviously, the lack of homogeneity in the number and quality of the data as well as the singularities of each area, mainly due to its bathymetry, will give rise to the definitions of the corresponding reliable parameters in the modeling process.

3. DESIGN AND LOGICAL STRUCTURE OF TIDAL DATA BASE

To build up the tidal data base has been, up to the moment, one of the main problems of the works we are carrying out. This is due to the difficulty to obtain the information, the lack of its uniformity and the versatility with which we want to provide the data base in relation with the variety of applications in the geodesy, oceanography and geophysics.

With the intention to obtain a flexibility and optimize the range of applications, the base has been provided with a set of characteristics which we summarize in the following points:

1.- Data bank is made of an exhaustive and ordered collection of information, jointly loaded avoiding harmful and unnecessary redundancies. Presently the number of stations included in the bank proceeding from many different sources is 291 (figure 2).

2.- The ENDIF program has been carried out to include new observations and modify or extract those already loaded. This program allows a permanent actualization of the data bank.

3.- Its logical structure (figure 3) allows an easy restructuring which is of a great utility if there is new information to add for some other applications. However, in its actual state it collects almost all existing data.

4.- Access to information is obtained with a suitable speed which allows to have the requested answer immediately delivered.

The 291 tidal stations presently included in the data bank come from the following sources:

* International Association for the Physical Sciences of the Ocean (IAPSO) of the IUGG.(Cartwrigth et al., 1979, 1985).

* Instituto Español de Oceanografía (Frutos Fernandez, 1973; García Lafuente et al., 1987).
* International Hydrographic Bureau (IHB).
* International Hydrographic Organization. IHO Tidal Constituent Bank.
* Instituto Hidrográfico de la Marina (IHMC).
* Silva (IHMC), personal comunication.
* Instituto Hidrográfico de Portugal (IHP). Tabla de Mares.
* Liverpool Tidal Institut (LTI).
* Cartwright, D.E., Edden, A.C., Spencer, R. and Vassie, J.M., 1980.
* Admiralty Tides Tables. The Hydrographer of the Navy, 1993.

The information with an overall of 30975 records has been collected in 10 different files (table 1) which were the sources to build up the data bank through the UNIM program. Among some other utilities, this program allows:

- To determine the Time Zone.
- To easy the observation epoch.
- To inform about the predominant tidal regime in the station area.
- To unify all the units adopted by the different organisms as information sources.
- To transform the observed phase lags through expressions

$$G_i(\phi,\lambda) = \psi^G_{ie} - \psi^P_i$$

$$k_i(\phi,\lambda) = G_i(\phi,\lambda) + m\lambda = \psi^P_{ie} - \psi^P_i$$

$$g_i(\phi,\lambda) = G_i(\phi,\lambda) + \omega_i S(\phi,\lambda)$$

where

m is the order of spherical harmonics,

ω_i the angular hour velocity of the corresponding harmonic

S the time zone

G_i the phase lag of the partial oceanic tide with respect to the equilibrium tide in Greenwich,

k_i the phase lag of the partial oceanic tide with respect to the equilibrium tide in the observation point,

g_i phase lag with respect to the equilibrium tide in Greenwich when we have expresed the observation time in local time.

- Provides the amplitude in centimeters and the various phase lag G, k, g for every one of the 60 harmonic included in the bank.
- Informs about the method of analysis used and the number of days used in such analysis.
- Provides the information about data variances and about residuals for every frequency band. These two statistics allow us to evaluate the ratio signal/noise and, therefore the standard deviation of the harmonic constants.
- It includes as an output of the program some other complementary information which can be of interest for some applications of the tidal bank such as:
  * the altitude in centimeters of the mean level over the hydrographic zero of the local chart of a higher scale (Z_o),
  * the link with the leveling network (ENR),
  * designation of the reference and the height (S_o) above it of the mean sea level observed,
  * the Altitude Unity (UA) and
  * the Common Establishment of the Port (EP).

4. APPLICATION PROGRAMS

The following are three application programs we have created (figure3):

SAEDIF program which allows complete or partial access to the information loaded in the bank with a bibliographic format.

SANIM program which provides the information about the mean levels Z_o and the heights S_o over the reference of the observed mean level.

SAMAR program, which allows the loading in CMS files of the information necessary to initiate the modeling process of a given harmonic.

Some other programs are not included in the diagram of figure 3, as they do not affect the building up process of the data bank and its applications. However, they are interesting for the investigations like those related to the analysis of ocean tidal observations. With this idea in mind, the authors have carried out in the I.A.G. two programs which are based on two different methodologies of analysis.They are: the MO88 program, mainly based on the least square technique and the LEMAG program which uses the Fourier analysis. Both programs are operative and with them we have analyzed some of the tidal data series incorporated in the BAMAG bank of the I.A.G.

5. MODELING

The modeling process initiates from the information provided by the data base of the SAMAR program.

First of all, by starting with the DERAP program we proceed to study and eliminate, when necessary, the harmonic constants which we can consider aberrant, either as a consequence of mistakes or, more often, due to the singularities of given tide records. It is well know that many of the tide records of the coast are located in ports, bays, river estuaries, etc., places where the local phenomena produce amplitude and phase values which are representative of such place and its surroundings. For that reason, they are singular observations which we must eliminate from the process of regional or global modeling we are working on, although they may have a great importance at a local level. The criteria followed for this selection is to consider that in a radius of around 100 km the spatial distribution of the gradients from different parameters should be homogeneous and uniform except for places such as straits where such regimes may substantially vary over lesser distances.

A second elimination program also carried out through the DERAP program consists of comparing every one and all of the parameters observed and calculated in one station (H, H_e, ψ, ψ_e, G, k, g) to those of other stations located in an area of one degree in latitude and longitude. The LEMAG program allows to calculate the theoretical parameters such as amplitudes and phases of the equilibrium tide for every one of the tidal stations (table 2). On figures 4 and 5 the spatial distribution of the harmonic constants which passed through the different tests for singularities detection can be seen.

We have processed the values of the amplitudes and the phases through a graphic program and we have plotted the isoamplitude and isophase lines for the western Mediterranean area, from the Gibraltar Strait till the natural barrier made by the Islands of Corsica and Sardinia and the group of small islands and bathymetric heights which we can consider that shape and close the western area of the "Mare Nostrum".

In parallel we have proceeded a subdivision of the area in trapeze shaped zones of 0.5 x 0.5 degrees and smaller ones in the coast band, in order to take into account, in this way, the real boundaries of this coast. The number and the dimensions of the spherical polygons for the area we are considering are:

197 -- $0\overset{\circ}{.}5000 \times 0\overset{\circ}{.}5000$
81 -- $0\overset{\circ}{.}2500 \times 0\overset{\circ}{.}2500$
156 -- $0\overset{\circ}{.}1250 \times o\overset{\circ}{.}1250$
2 -- $0\overset{\circ}{.}0625 \times 0\overset{\circ}{.}0625$

The central points of all polygons shape the digital network of the chart to which values are assigned by interpolation between the amplitude and phase lines next to that very center. The group of these values ordered by geographic coordinates forms the digital chart of the studied area (figures 6 and 7). The whole modeling process is carried out through the MODEL ARMONI program which allows to create a file which contains for every polygon the average amplitude of the tide, measured in centimeters, the average differences with respect to the equilibrium tides in Greenwich meridian measured in degrees, and the geographic coordinates of the center and surface of the polygon calculated from the DESUP program.

REFERENCES

Admiralty Tide Tables, 1993. Volume 1: European Waters, including Mediterranean Sea. Pub. The Hydrographer of the Navy (UK), NP 201-93 438 pp.

Cartwright, D.E. Zetler , B.D., and Hamon, B.V., 1979. Pelagic Tidal Constant. IAPSO Pub. Sc. 30, 65 pp.

Cartwright, D.E., Edden, A.C., Spencer, R. and Vassie, J.M., 1980. The tides of the Northeast Atlantic Ocean. Phil. Trans. R. Soc. Lond. A., vol. 298.

Cartwright, D.E. and Zetler ,B.D., 1985. Pelagic Tidal Constant 2. IAPSO. Pub. Sc. 33, 59pp.

García Lafuente, J., Castillejo, F. and García, M., 1987. Resultados de la red mareográfica del Estrecho de Gibraltar. Rev. de Geofísica (1987) 43, 37-56.

Frutos Fernández, 1973. Constantes armónicas de marea de la zona del Estrecho de Gibraltar. Bol. IEO, 169.

Frutos Fernández, 1973. Constantes armónicas de marea de las Islas Baleares, Canarias y Costa Occidental de Africa.Bol. IEO, 170.

Schwiderski, E.W., 1980. Ocean Tides, Part. I: Global Ocean Tidal Equations. Marine Geodesy 3: 161.

Schwiderski, E.W., 1980. Ocean Tides, Part. II: A Hydrodinamical Interpolation Model. Marine Geodesy 3: 219.

Schwiderski, E.W., 1980. On Charting Global Ocean Tides. Rev. Geophysics and Space Physics 18, 1, 243-268.

Schwiderski, E.W., 1983. Atlas of Ocean Tidal charts and maps, I, The semidiurnal lunar tide M2. Marine Geodesy, 6, 219-265.

Toro, C., 1989. Determinación y evaluación de las variaciones periódicas de la gravedad y de las desviaciones de la vertical en la Península Ibérica producidas por las mareas oceánicas. Ph.D. Thesis, Fac. CC. Matemáticas. Universidad Complutense de Madrid, 378 pp.

Vieira, R., Toro, C. and Sukhwani, P.K., 1983. Ocean effects on Gravity Tides in the Iberian Peninsula. In: J.T. Kuo (Sc.Ed.), Proc. 9th Int. Symp. Earth Tides, New York 1981. Schweizerbart'she Verlag., Stuttgart, 403-410.

Vieira, R., Toro, C. and Megias, E., 1986. Ocean Tides in the nearby of the Iberian Peninsula. Part I: M2 Iberia Map. In : R. Vieira (Sc. Ed.), Proc. 10th Int. Symp. Earth Tides, Madrid 1985. Consejo Superior de Investigaciones Científicas, 679-696.

Vieira, R., Toro, C. and Fernandez, J., 1986. Ocean Tides in the nearby of the Iberian Peninsula. Part II: S2 Iberia Map. In: R. Vieira (Sc. Ed.), Proc. 10th Int. Symp. Earth Tides, Madrid 1985. Consejo Superior de Investigaciones Científicas, 697-706.

Vieira, R., Fernandez, J., Toro, C. and Camacho, A.G., 1991. Structural and oceanic effects in the gravimetric tides observations in Lanzarote (Canary Islands). In: J. Kakkuri (Sc. Ed.), Proc. 11th Int. Symp. Earth Tides, Helsinki 1989. Schweizerbart'sche Verlag., Stuttgart, 217-230.

INDEX OF THE ILLUSTRATIONS

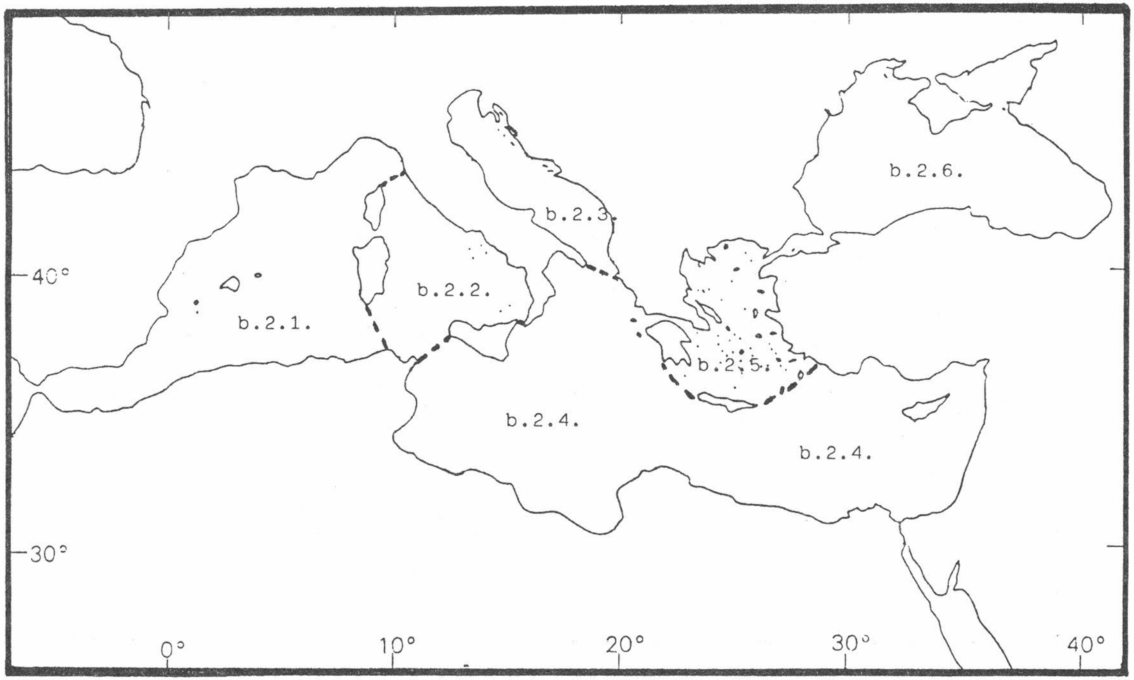


Figure 1. MEDITERRANEAN SEA. MODELING AREAS.

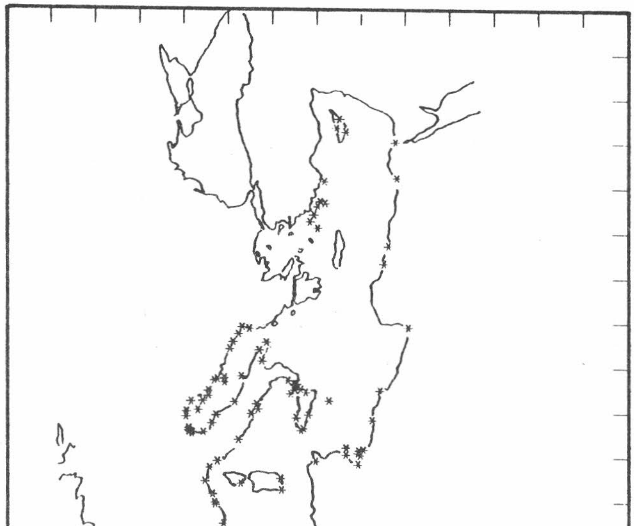


Figure 2. MAREOGRAPHIC DATA

Figure 3. BLOCK SCHEME OF THE MAREOGRAPHIC DATA BASE.

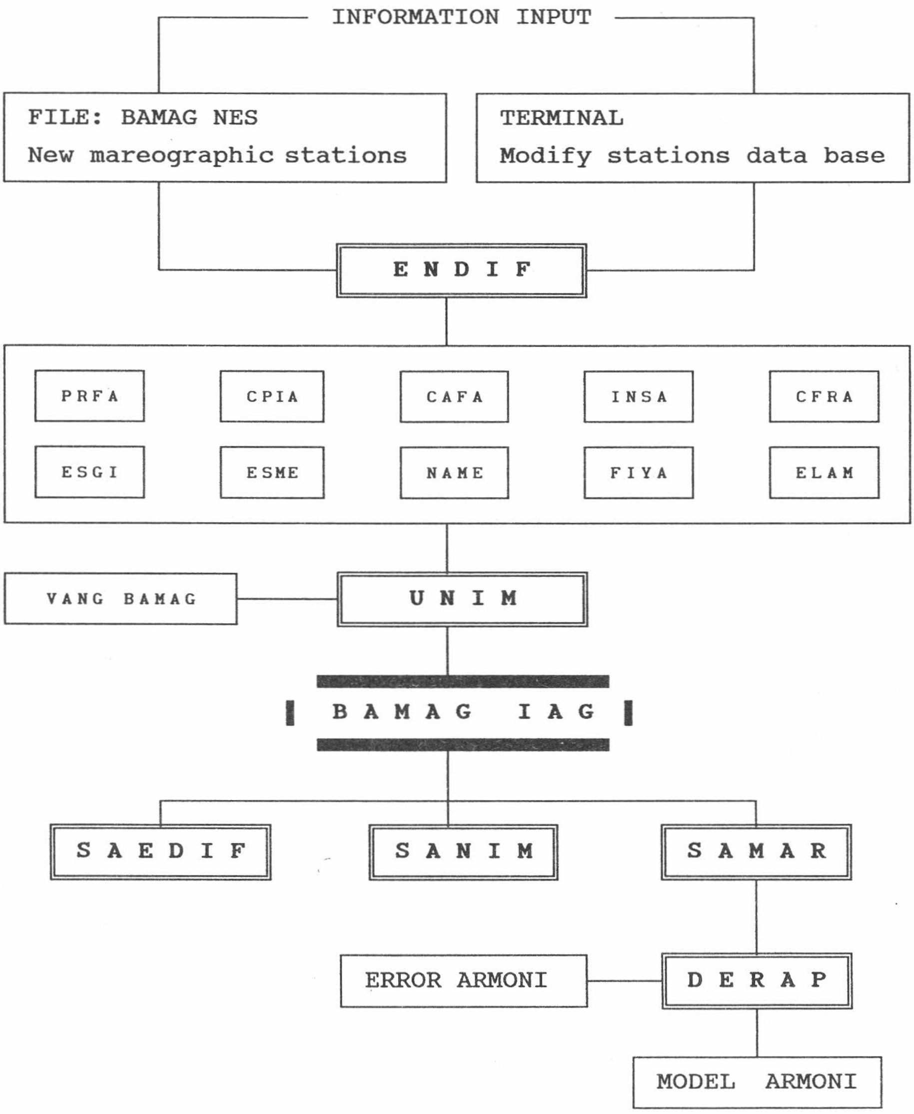


Table 1. MAREOGRAPHIC DATA BANK. LOGICAL DESCRIPTION OF THE SOURCE FILES.

CODE	DESIGNATION FILE	TIDE GAUGES NUMBER	RECORDS	DESCRIPTION
20	PRFA	53	5800	Pelagic Tidal Constants. Northeast Atlantic Ocean.
11	CPIA	48	5296	Shore mareographic stations located along the atlantic Iberian Peninsula coast.
12	CAFA	14	1487	Shore stations located along the atlantic African coast.
13	INSA	29	3114	Atlantic island stations.
14	CFRA	22	2303	French atlantic stations.
15	ESGI	20	2185	Gibraltar strait.
16	ESME	7	760	Spanish stations in the Mediterranean Sea.
17	NAME	20	2098	Mediterranean African coast: from Gibraltar strait to Syria - Turkey border, including spanish stations.
18	FIYA	66	6886	Mediterranean shore stations of France, Monaco, Italy, Yugoslavia and Albania.
19	ELAM	12	1046	Greece tide gauges, mareographic stations in the Mediterranean coast of Minor Asia and Black Sea area.

Table 2. M2 COMPONENT. STRAIT OF GIBRALTAR AND MEDITERRANEAN SEA.

MAREOGRAPHIC STATION	ZONE	LATITUDE	LONGITUDE	D/S	H(CM)	G(GR)
15001 ALGECIRAS (1)	11.1.2011.111	36.1333	-5.4500	.0	31.3	52.0
15002 ALGECIRAS (2)	11.1.2011.111	36.1167	-5.4333	.0	33.5	51.5
15003 ALGECIRAS (3)	11.1.2011.111	36.1333	-5.4500	.0	32.3	43.8
15004 BARBATE	11.1.1033.111	36.1833	-5.9167	.0	45.8	62.1
15005 CABO ESPARTEL	11.1.2011.111	35.7650	-5.9433	.0	75.8	67.0
15006 CABO TRAFALGAR	11.1.2011.111	36.1717	-6.0300	.0	76.2	53.5
15007 CEUTA (1)	11.1.2011.111	35.9050	-5.2983	.0	29.9	47.5
15008 CEUTA (2)	11.1.2011.111	35.8833	-5.2667	.0	28.8	55.0
15009 GIBRALTAR	11.1.2011.111	36.1333	-5.3500	.0	29.8	46.2
15010 SANDY BAY (GIBRALTAR)	11.1.2011.111	36.1333	-5.3333	.0	27.0	46.0
15011 PUNTA ALBOASA	11.1.1033.111	35.8333	-5.7000	.0	52.0	69.0
15012 PUNTA CAMARINAL	11.1.1033.111	36.0833	-5.8000	.0	65.0	49.0
15013 PUNTA CARNERO	11.1.2011.111	36.0717	-5.4283	.0	31.1	47.5
15014 PUNTA CIRES	11.1.2011.111	35.9117	-5.4800	.0	36.4	46.5
15015 PUNTA GRACIA	11.1.2011.111	36.0900	-5.8100	.0	64.9	49.0
15016 PUNTA KANKOUSH	11.1.2011.111	35.8417	-5.7000	.0	51.8	69.0
15017 TANGER (1)	11.1.1033.111	35.7500	-6.0167	.0	68.9	69.9
15018 TANGER (2)	11.1.1033.111	35.7833	-5.8000	.0	68.2	66.7
15019 TARIFA (1)	11.1.1033.111	36.0033	-5.6067	.0	41.5	57.0
15020 TARIFA (2)	11.1.1033.111	36.0033	-5.6067	.0	40.2	41.1
16001 ALICANTE	11.1.2211.113	38.3333	-.4833	.0	2.0	58.0
16002 ALMERIA	11.1.2211.112	36.8333	-2.4833	.0	9.0	51.0
16003 BARCELONA	11.1.2211.113	41.5167	2.0000	.0	4.4	207.2
16004 CHAFARINAS	11.1.2211.116	35.1833	-2.4333	.0	11.7	99.6
16005 MALAGA	11.1.2211.112	36.7167	-4.4167	.0	16.3	60.5
16006 PALMA DE MALLORCA	11.1.2211.115	39.5500	2.6333	.0	2.8	210.2
16007 ROSAS	11.1.2211.113	42.2333	3.2667	.0	5.5	250.4
17001 ALHUCEMAS (1)	11.1.2211.116	35.2333	-3.8833	.0	18.5	60.7
17002 ALHUCEMAS (2)	11.1.2211.116	35.3333	-3.8667	.0	17.9	54.7
17003 VILLA NADOR	11.1.2211. 16	35.0900	-2.9167	.0	6.0	163.0

MAREOGRAPHIC STATION	ZONE	LATITUDE	LONGITUDE	D/S	H(CM)	G(GR)
17005 ALGER	11.1.2211.116	36.7833	3.0667	.0	2.4	219.3
17006 LA GOULETTE	11.1.2222.117	36.8167	10.3167	.0	8.0	249.0
17007 GABES	11.1.2244.117	33.8833	10.1167	.0	48.0	121.9
17008 HOUMT ADJIM	11.1.2244.117	33.7167	10.7500	.0	31.0	103.0
17009 SFAX	11.1.2244.117	34.7333	10.7667	.0	42.0	77.0
17010 HOUMT SOUK	11.1.2244.117	33.8833	10.8667	.0	31.0	104.0
17011 RAS TOURG-EN-NESS	11.1.2244.117	33.8167	11.0500	.0	27.0	69.0
17012 ZARZIS	11.1.2244.117	33.5000	11.1167	.0	22.0	77.0
17013 EL ABASSIA	11.1.2244.117	34.7167	11.2500	.0	26.0	83.0
17014 TRIPOLI (TARABULUS)	11.1.2244.117	32.9000	13.1833	.0	13.0	65.0
17015 MISURATA	11.1.2244.117	32.3667	15.2167	.0	7.0	53.0
17016 MESA EL BREGA	11.1.2244.117	30.4167	19.5833	.0	5.0	60.0
17017 MERSA TOBRUK	11.1.2244.118	32.0833	23.9667	.0	1.0	285.0
17018 BARDIA	11.1.2244.118	31.7667	25.1667	.0	3.0	236.0
17019 ALEJANDRIA	11.1.2244.118	31.1667	29.8500	.0	7.0	245.0
17020 PORT SAID	11.1.2244.118	31.2667	32.3167	.0	12.0	240.0
18001 PORT VENDRES	11.1.2211.114	42.5167	3.1000	.0	5.0	288.0
18002 MARSELLA	11.1.2211.114	43.3000	5.3667	.0	7.0	217.0
18003 TOLON	11.1.2211.114	43.1167	5.9333	.0	3.0	266.0
18004 NIZA	11.1.2211.114	43.7000	7.2833	.0	7.0	244.0
18005 MONTE CARLO	11.1.2211.114	43.7333	7.4167	.0	4.0	259.0
18006 AJACCIO	11.1.2211.119	41.9333	8.7500	.0	7.0	250.0
18007 CAGLIARI	11.1.2222.119	39.2000	9.1000	.0	8.0	236.0
18008 CARLO FORTE	11.1.2212.114	39.1500	8.3000	.0	6.0	231.0
18009 IMPERIA	11.1.2211.120	43.8833	8.0167	.0	8.0	237.0
18010 GENOVA	11.1.2211.120	44.4000	8.9000	.0	8.0	222.0
18011 LA ESPEZIA	11.1.2211.120	44.0667	9.8500	.0	9.0	215.0
18012 LIVORNO	11.1.2212.120	43.5500	10.3000	.0	8.0	232.0
18013 CIVITAVECCHIA	11.1.2222.120	42.1000	11.7833	.0	11.0	239.0
18014 GAETA	11.1.2222.120	41.2167	13.5833	.0	11.0	234.0
18015 NAPOLES	11.1.2222.120	40.8333	14.2667	.0	11.0	237.0
18016 ISCHIA	11.1.2222.120	40.7333	13.9333	.0	12.0	232.0

MAREOGRAPHIC STATION	ZONE	LATITUDE	LONGITUDE	D/S	H(CM)	G(GR)
18017 TROPEA	11.1.2222.120	38.6833	15.9000	.0	15.0	242.0
18018 VILLA SAN GIOVANNI	11.1.2224.120	38.1833	15.6333	.0	3.0	85.0
18019 REGGIO CALABRIA	11.1.2224.120	38.1167	15.6500	.0	6.0	62.0
18020 TAORMINA	11.1.2244.121	37.8167	15.2833	.0	9.0	57.0
18021 MESSINA	11.1.2224.121	38.2167	15.5667	.0	5.0	2.0
18022 CAPO PELORO	11.1.2224.121	38.2667	15.6500	.0	5.0	238.0
18023 LIPARI	11.1.2222.120	38.4833	14.9667	.0	12.0	232.0
18024 MILAZZO	11.1.2222.121	38.2167	15.2500	.0	12.0	234.0
18025 PALERMO	11.1.2222.121	38.1333	13.3333	.0	11.0	232.0
18026 MARSALA	11.1.2224.121	37.8000	12.4333	.0	7.0	207.0
18027 MAZARA DEL VALLO	11.1.2224.121	37.6333	12.5833	.0	4.0	128.0
18028 PORTO EMPEDOCLE	11.1.2244.121	37.2833	13.5333	.0	5.0	76.0
18029 CATANIA	11.1.2244.121	37.4833	15.1000	.0	6.0	61.0
18030 VALLETTA	11.1.2244.122	35.8833	14.5167	.0	7.0	48.0
18031 TARANTO	11.1.2244.120	40.4667	17.2167	.0	6.0	71.0
18032 OTRANTO	11.1.2234.120	40.1500	18.5000	.0	7.0	73.0
18033 BRINDISI	11.1.2233.120	40.6500	17.9667	.0	9.0	73.0
18034 VIESTE	11.1.2233.120	41.8833	16.1833	.0	8.0	61.0
18035 ORTONA	11.1.2233.120	42.3500	14.4167	.0	7.0	64.0
18036 ANCONA	11.1.2233.120	43.6167	13.5000	.0	7.0	303.0
18037 PESARO	11.1.2233.120	43.9167	12.9167	.0	13.0	288.0
18038 PORTO CORSINI	11.1.2233.120	44.5000	12.2833	.0	15.0	274.0
18039 CHIOGGIA	11.1.2233.120	45.2333	12.3000	.0	22.0	273.0
18040 MALAMOCCO	11.1.2233.120	45.3333	12.3167	.0	23.0	267.0
18041 VENECIA	11.1.2233.120	45.4333	12.3333	.0	24.0	285.0
18042 GRADO	11.1.2233.120	45.6833	13.3833	.0	23.0	276.0
18043 TRIESTE	11.1.2233.120	45.6500	13.7500	.0	26.5	302.5
18044 SAN GIULANO	11.1.2233.120	45.4667	12.2833	.0	24.0	306.0
18045 TORCELLO	11.1.2233.120	45.5000	12.4167	.0	19.6	345.8
18046 PALIAGAO	11.1.2233.120	45.5167	12.3833	.0	19.8	12.8
18047 TORSON DI SOTO	11.1.2233.120	45.5000	12.4167	.0	20.8	342.8
18048 MILLECAMPI	11.1.2233.120	45.3000	12.1833	.0	16.9	18.4

MAREOGRAPHIC STATION	ZONE	LATITUDE	LONGITUDE	D/S	H(CM)	G(GR)
18049 PORTO PIAVE VECCHIA	11.1.2233.120	45.4867	12.5783	.0	22.3	307.2
18050 CAVALLINO	11.1.2233.120	45.5000	12.4167	.0	10.7	39.8
18051 PULA	11.1.2233.123	44.8667	13.8333	.0	15.0	236.0
18052 RIJEKA (FIUME)	11.1.2233.123	45.3333	14.4333	.0	10.0	220.0
18053 SENJ	11.1.2233.123	45.0000	15.9000	.0	10.0	211.0
18054 MALI LOSINJ	11.1.2233.123	44.5333	14.4667	.0	8.0	211.0
18055 ZALIV PANTERA	11.1.2233.123	44.1500	14.8500	.0	4.0	165.0
18056 ZADAR	11.1.2233.123	44.1333	15.2000	.0	6.0	203.0
18057 SIBENIK	11.1.2233.123	43.7333	15.9000	.0	6.0	106.0
18058 ROGOZNICA	11.1.2233.123	43.5333	15.9833	.0	6.0	111.0
18059 SPLIT	11.1.2233.123	43.0500	16.0833	.0	8.0	100.0
18060 KOMIZA	11.1.2233.123	43.0500	16.0833	.0	7.0	79.0
18061 OTOK SVTAC	11.1.2233.123	43.0333	15.7667	.0	7.0	93.0
18062 DUBROVNIK	11.1.2233.123	42.6667	18.0667	.0	9.0	86.0
18063 MELJINE	11.1.2233.123	42.4500	18.5500	.0	9.0	70.0
18064 BAR	11.1.2233.123	42.0667	19.0833	.0	9.0	80.0
18065 SHENGJIN	11.1.2233.123	41.8167	19.5833	.0	9.0	79.0
18066 DURRES	11.1.2233.123	41.3167	19.4500	.0	9.0	73.0
19001 NISOS LEROS	11.1.2255.124	37.1667	26.8333	.0	3.0	304.0
19002 NISOS ASTIPALAIA	11.1.2255.124	36.6333	26.3833	.0	3.0	295.0
19003 NISOS KOS	11.1.2255.124	36.8833	27.3167	.0	4.0	271.0
19004 NISOS SIMI	11.1.2255.124	36.6167	27.8667	.0	4.0	269.0
19005 RODHOS	11.1.2244.124	36.4500	28.2333	.0	5.0	250.0
19006 LINDHOS	11.1.2244.124	36.1000	28.1000	.0	6.0	249.0
19007 MEYISTI	11.1.2244.125	36.1500	29.6000	.0	7.0	245.0
19008 KYRENIA	11.1.2244.126	35.3333	33.3167	.0	10.1	8.6
19009 LIMASSOL	11.1.2244.126	34.6667	33.0500	.0	10.0	235.0
19010 FAMAGUSTA	11.1.2244.126	35.1167	33.9500	.0	11.0	236.0

Figure 4. MEDITERRANEAN SEA. TIDAL CONSTITUENT M2. AMPLITUDE H (cm).

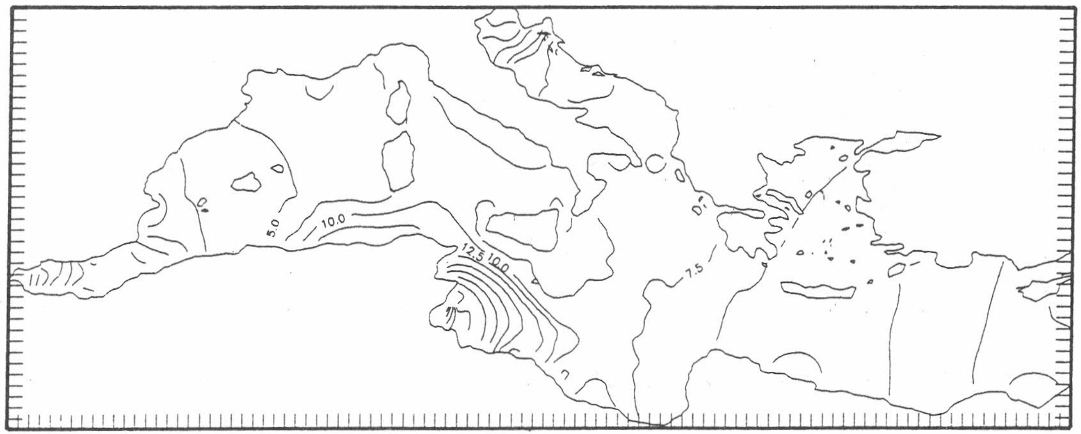
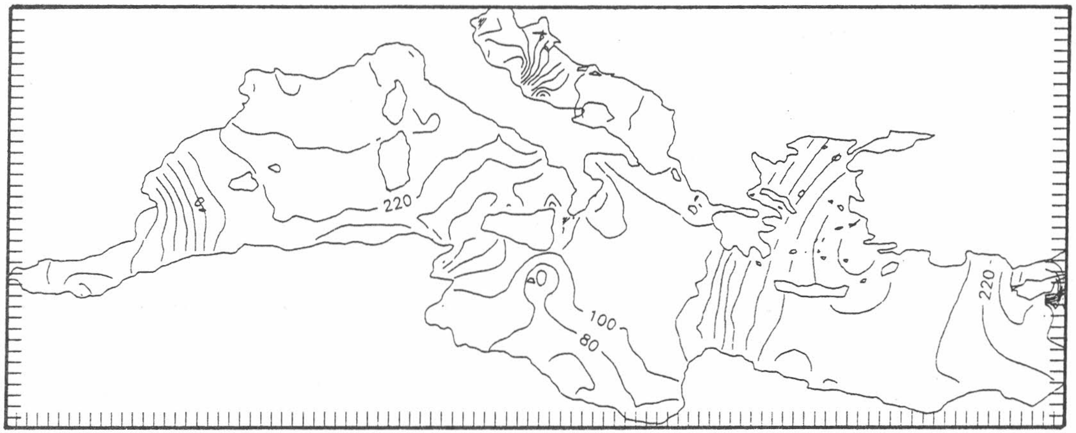


Figure 5. MEDITERRANEAN SEA. TIDAL CONSTITUENT M2. PHASE LAG G (degrees).



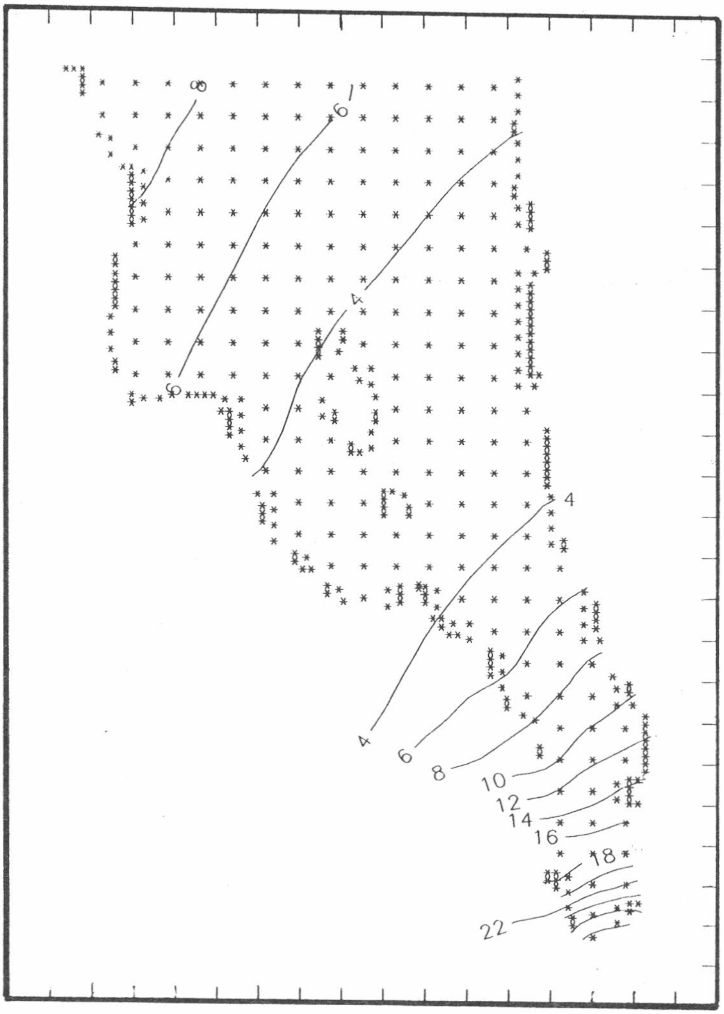


Figure 6. WEST MEDITERRANEAN SEA. TIDAL CONSTITUENT M2. AMPLITUDE H (cm).

Figure 7. WEST MEDITERRANEAN SEA. TIDAL CONSTITUENT M2. PHASE LAG G (degrees).